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Paradigm shift in engineering education More *time* is needed

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Abstract

The trouble with our times is that the future is not what it used to be.
 Paul Valéry

Information Technology (IT) becomes: innovation motor, engineering toolbox; basic part of curricula. The impact on engineering education is due to shifting from industrial towards post-industrial engineering. IT is the most suitable domain to bear the paradigmatic shifts able to lessen the paradox of temporal dissociation between the *present* process of teaching and its *future* mirroring in life-long learning. Hence, a modern approach to time and to its related concepts is focused upon. The essence of applying new paradigms in education is exemplified via the advanced subdomain of artificial intelligence. Conclusion: carrying out such educational innovations is urgent, painless and affordable.

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Keywords: Lisbon objectives; post-industrial engineering; lifelong learning; paradigmatic shift; temporal dimension; agent-orientation.

1. Introduction

The paper develops, illustrates, and details two very recent papers (Oprean et al., 2009; Kifor et al., 2009) on preparing Engineering Education (EE) for approaching the Lisbon objectives. From a broader perspective, this paper is the last from a series of five, embodying some milestones of a long-term endeavour. The first two papers (Oprean, 2009; Oprean et al., 2009a), having the role of a prolegomenon for the third one, where condensed in nuce there: “was a broad outline of its very title, the author blending the educated guess of a manager with the “educated vision” of a doctoral advisor”. The paper written by Oprean et al. (2009a) was “a kind of exploratory leap [...]: the first Romanian project to apply agent-oriented paradigms in [...] industrial environments; thus, it appears as one of the first European attempts to adjust quality management to the Knowledge Society”.

Since the solution proposed by Kifor et al. (2009) for EE was “dense teaching” based on the concept of “*e-maieutics*” (Bărbat, 2008a) (because focus must move for students from knowledge to skills and for educators from teaching, to training, to catalyse), Information Technology (IT), as key factor of the KS, is seen as innovation motor,

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main engineering toolbox, and basic part of any curriculum (“Knowledge has always been an ingredient of human societies, but what is radically new is the speed of its accumulation and diffusion, due to information and telecommunications technologies” (Ziya Aktaş, 2005)). However, considering the conference perspective, the focus is on aspects relevant for modern education all in all, using EE just as instance and avoiding technicalities – above all those regarding IT. Thus, the rest of the paper is organised as follows: After presenting *related work and approach* in Section 2, in Section 3 is investigated the focal point of post-industrial engineering, i.e. *designing services instead of products*. A modern approach to *time* is focused upon, together with the main engineering tool *Computer-Aided “x”* insisting on *transdisciplinary links* (Section 4). *Conclusions and future work* close the paper (Section 5).

2. Related Work and Approach

To impair intense redundancy with the previous papers (published all in 2009), both related work and approach should be reduced to minor updates and adjusted to the conference scope:

Related work. To get things clear, some modern claims about e-learning the paper totally agrees with Conner (2007): “E-learning will be considered any pedagogy (andragogy) that utilizes the Internet for communication”. “E-learning should not be confused with distance education. Distance education is a program format in which the learners and instructors are geographically separate. While E-learning can be used in this format, it can also be used in an onsite program. Some programs allow learners the flexibility of moving in and out of f2f, distance education and E-learning through out their academic career” “Another form of E-learning is independent study”. “The main theoretical bases upon which E-learning revolves are andragogy and constructivism. Andragogy is a term that refers to the teaching methodology that best facilitates learning in the adult. Constructivism refers to the belief that learning occurs as a result of the learner thinking about and interacting with the subject matter” (Conner, 2007). Likewise, “Lifelong learning is now recognized by educators, governing bodies, accreditation organizations, [...], and the general public as one of the most important competencies that people must possess. Promoting lifelong learning as [...], broad in domain, [...], and applicable to one’s profession as well as all aspects of one’s life has emerged as a major global educational challenge” (Collins, 2009).

Some examples regarding complex engineering disciplines: “Mechatronics has become a familiar term in the field of engineering worldwide, but [...] its full potential is yet only partially expressed. [...] the transdisciplinary approach opens a new perspective on its development”, Mechatronics [makes] the computer a part of the machine that builds a product [and] gives to the new mechatronical engineer a synergistic perspective on knowledge” (Pop, 2009). Likewise, “A marine engineer, educated to work mainly on seagoing ships, has an expected professional life of about 40 years, both at sea and on shore facilities. Therefore, the education he/she should have should address the expected innovations of the few decades to come” (Ünsalan et al., 2009). For food EE a case study is given in Mironescu et al. (2009). Finally, the need for holistically approached education is underlined for the post-industrial age in (Pink, 2005): “just as information workers surpassed physical laborers in economic importance”; moreover, the support for “R-directed thinking” is changed into prophecy: “the workplace terrain is changing yet again, and power will inevitably shift to people who possess strong right brain qualities”.

Approach. The paper objectives were not stated as usual at the beginning because conclusions would have been irrelevant. (Indeed, neither paradigm shifts nor LL could be nailed down during a research.) The paradox is avoided changing McLuhan’s phrase “the medium is the message” into “the approach is the target”. Thus, the conclusions drawn by Oprean et al. (2009) and by Kifor et al. (2009) – focusing on the inexorable paradigmatic shifts involved – are taken here as “starting vector” (its components become premises, criteria or working hypotheses). The main impact on EE is due to the shift from industrial towards post-industrial engineering, i.e., moving the emphasis from developing *products* towards developing *services*. IT seems to be the most suitable domain to bear most paradigmatic shifts involved because of five reasons: a) It is the only affordable way to solve or lessen the paradoxes due to the intrinsic temporal dissociation between the *present* process of teaching and its expected *future* mirroring in lifelong learning (LL) (Oprean, 2009). b) The EU included the “digital competence” among the eight key competences for lifelong learning (CEC, 2009) while many universities consider already these competences in setting up their educational strategies (Grünwald et al., 2009). c) Albeit in yet quite primitive manner, IT is able to take into account the high dynamics and uncertainty of both industrial and educational environments of the near future (on the contrary, most current EE curricula disregard the main features of KS (Oprean et al., 2009)). d) Even

within the framework of the industrial age paradigms, EE – and engineering as a whole – was permeated by “Computer-Aided “x”” where *x* stays for any engineering subdomain (Bărbat, 2008a). e) IT itself is yet far from completing its own paradigmatic shifts (e.g., moving from object-based to agent-based software is mandatory for designing efficiently processes) (Dziñac et al., 2009).

Hence, the approach is in line with the perspective of the four preceding papers: “architectural, basically holistic, top-down, and based on advanced, state-of-the-art concepts like: niche transdisciplinary research merging synergistically vital strands explored before; open, uncertain, and dynamic environments; anthropocentric systems; cognitive ergonomics; life-long learning. The approach is also pragmatic, reorienting – with minimal redundancy – the investigation from industrial to educational environments” (Oprean et al., 2009).

3. Designing Services Instead of Products

In the “robot-portrait of an postindustrial engineer” (Kifor et al., 2009) the main features of the KS engineering profession were “stated standing out against their counterparts in customary, traditional, engineering; to emphasise the change [...] the features are expressed as “From ...to”. Abridged from (Dziñac et al., 2009) these shifts are: a) Environment: *deterministic* (closed, static, known) / *nondeterministic* (open, dynamic, partially unknown). b) *Well-defined problem* (*quantity*, precision, certainty) / *fuzzy-defined situation* (*quality*, vagueness, uncertainty). c) *Solving problems* (stability, efficiency, reliability) / *managing situations* (effectiveness, flexibility, robustness). d) *Solutions* (lasting, optimal, apodictic) / *answers* (temporary, acceptable, revisable). e) Design: *technocentric* (based on efficiency, accuracy, and complex functionality) / *anthropocentric* (based on value theory, fuzziness, and simple interfaces).

All feature shifts can be broadened to other KS professions but the last one is paramount, because teaching is a service and should be anthropocentric *par excellence*. Thus, “The knowledge-based society entails new targets for e-Learning because: a) Humans must (inter)act [...] quite different to the way they are familiar with. b) The challenges to cope with are major and involve other requirements. c) The information and communication technologies (ICTs) advanced dramatically offering possibilities [...] and approaches unthinkable about forty years ago when e-Learning took off. d) Without an anthropocentric and transdisciplinary approach end-user acceptance will not be in line with the huge technological potential on hand” (Bărbat, 2008). As regards anthropocentric design, *anthropocentrism* means “focusing on the human being as user, beneficiary, and, ultimately, *raison d'être* of any application or, more general, technology” (Bărbat et al., 2007). Moreover, “*anthropocentric*” has two – convergent but distinct – connotations: for the wide-ranging Lisbon target it means a *stance* (without a human-centred perspective the Knowledge Society is vain – in all meanings of the word) while for the current objectives it embodies the very *approach*” (Oprean et al., 2009a). (This paradigm shift was labeled by Dziñac et al. (2009): from “Kelvin-Number-Oriented” to “Zadeh-Word-Oriented”).

In short, “it is a paradigmatic shift from the “*Producer-Consumer*” paradigm of the industrial era to the – much more dynamic – “*Client-Server*” paradigm of the postindustrial one. (It is a telling undertone in the order of the two entities: in line with the still reigning paradigm, the beneficiary is the second, whereas in the arising one, he/she is the first. [...] for IT even the “*Client-Server*” paradigm becomes obsolete.) [...] the postindustrial engineer is immersed in a “Continuum of Learning”” (Kifor et al., 2009).

The essence of applying new paradigms in engineering as a whole and in EE in particular is exemplified below via the forward-looking IT subdomain of artificial intelligence, focusing on its flagship: *agent-orientation*.

4. Time to Deal With Time, Computer-Aided “x”, and Transdisciplinary Links in Agent-Oriented

Time is the paper’s conceptual core because “validating anthropocentric applications is done exclusively by the end-user” (Oprean et al., 2009; Kifor et al., 2009), i.e. the learner. On the other hand, the “baffling, yet unsolved, paradox to cope with” (Oprean, 2009) inherent to LL “stems from a kind of “temporal contradiction”, i.e., how to organize institutional *teaching*, clearly limited in both time (in line with the shortened Bologna degree framework) and objectives (in line with the focused curricula) to meet the expectations of a free, dynamic, and indistinct environment, as implied by the concept of life-long *learning*. The inconsistency is deeply rooted in traditional perceptions about the educational process itself, seen as requiring a face-to-face relationship between teacher and student. Since it is obvious that the processes of teaching and learning cannot be anymore synchronous, with the

student and teacher sharing knowledge in the same space and time, a totally new educational approach is badly needed” (Oprean, 2009). Moreover, the impact of time-related concepts is suggested by the paper title (both the need for a powerful temporal dimension in EE and the trouble to assimilate the speed of change), the motto (increased uncertainty of the future), and the section title (both priority and need to cope with time in education). Another vital concept (hardly perceived outside the IT community as being time-related) is *parallelism* (to interact efficiently, entities – natural or artificial alike – must be somehow “syn-chronous” or “con-temporaneous”). The polymorphism of time itself has been investigated by Bărbat, (2008a) and by Georgescu et al. (2008) while time-related concepts were studied conceptually by Bărbat (2008) and by Dziřac et al. (2009) and applied to learning by the same authors.

Computer-Aided “x”. The Chinese proverb “Tell me and I’ll forget; show me and I may remember; involve me and I’ll understand” was revisited in the prehistory of this research: usually seen, from an anthropocentric perspective, as comparing three *ways of learning* it was considered as revealing three *ages of e-Learning*. To shift from the (yet prevailing) second age to the third one (entailed by KS), most software engineering mechanisms applied in “Computer-Aided x”, “where x stays for almost any intellectual activity” (Bărbat, 2008) (including high-quality teachware) must be innovated. Indeed, “available software tools are either hardly affordable (because of high complexity – both cognitive and structural) or rather ineffective (designed for other environments, applied to ill-defined problems or lacking expected functionality). For instance, the very concept of “uncertainty” was treated inadequately – regardless of [...] end-user expectations (requesting anthropocentric interfaces)” (Bărbat, 2007). So far such mechanisms were devised and “tested for $x = \{\text{Decision, Learning, Semiosis}\}$, but only in solving toy problems” (Bărbat, 2008).

Focusing now the analysis on LL, there are three vital paradigmatic changes: a) The very approach to learning must shift from “*reductionist*, analytic, algorithmic, apodictic reasoning to *holistic*, synthetic, non-algorithmic, revisable reasoning. (In other words, from solely *left-brain* inference chains to a blend of reasoning tactics from *both* brain hemispheres. Otherwise, why do we have both of them?)” (Bărbat et al., 2007; Bărbat, 2007a; Kifor et al., 2009). b) The target of learning must shift from “*know* to *know-how*. The (more than forty years old) lengthy shift from data-driven static knowledge towards event-driven dynamic knowledge (i.e. skills) [...] could be seen as the foundation of any higher education in the KS” (Kifor et al., 2009). c) Assessment of learning must shift from “the serenity offered by *testing* (based on design specifications) to the worry involved by *validating* (based on end-user satisfaction)” (Bărbat, 2007a; Kifor et al., 2009; Oprean et al., 2009; Oprean et al., 2009a). d) IT must shift from *photo* to *movie*, namely from “conventional *e-learning* with *programs* as software entities (*objects* devised as *tools*) to innovative *e-training* with *agents* as software entities (*processes* devised as *interactants*)” (Dziřac et al., 2009; Kifor et al., 2009). In short, LL involves “metaskills” (skills to acquire skills), i.e., “how to know how” (Kifor et al., 2009).

Transdisciplinary Links in Agent-Oriented. Focus is on the intrinsic – almost osmotic – links between LL and *transdisciplinarity* (mainly involving niche or emerging subdomains) as well as on the trend to return to a holistic, anthropocentric approach in education. “Despite the fact that human-centeredness was acknowledged – already in Socrates’ times – as a key feature of any educational undertaking, no modern university is perceived by its stakeholders as “anthropocentric enough”, while improving academic quality management is a cardinal concern for every Rector. [...] Strange enough, as regards teaching the shift was rather in the opposite direction: the highly contextual Socratic “duologue-based-maieutics” needed no grades” (Oprean et al., 2009). (As regards the innovative aspects of this research, prior work of the authors was presented in the papers mentioned above and in the books or papers referred to there.) Agent-based applications in economy, medicine, chemistry, physics, etc. must be based on “Just In Time” and on bounded rationality (Bărbat et al., 2007; Bărbat, 2007a; Georgescu et al., 2008). Thus precision is not just costly (Zadeh, 2008), but becomes unnecessary and even harmful (Bărbat, 2008a), while the conceptual framework of IT should move from *numeric* (mathematical) precision to *textual* (semiotic) ambiguity (Bărbat, 2007a; Bărbat, 2008a; Zadeh, 2008). Even syllabi for conventional pre-Gödelian mathematics tend to become “less algorithmic” because “*learning* (at least, high-level one) is innately non-algorithmic” (Golfin et al., 2005; Anderson et al., 2009) or, at least, more modern (e.g., the curriculum outline for marine engineering at Bachelor of Science level given in (Ünsalan et al., 2009) includes vector analysis after analytic geometry).

5. Conclusions and Future Work

Because of the temporal dissociation between teaching and learning entailed by LL, the conclusions are in fact expectations and regard rather the journey than the destination. There are three time horizons:

Short range (educated guess): a) The approach is workable. b) Paradigmatic shifts are urgent in EE (mainly for teachers). c) Carrying out educational innovations is technologically easy and economically affordable. d) On the contrary, changing mentalities is challenging and requires a long time.

Middle range (probable benefits): a) *EE researchers*: are encouraged to investigate transdisciplinary niches, holistic approaches, and right-brain tactics. b) *Academics*: are urged to update all kind of curricula, focusing on new paradigms. c) *EE quality assessors*: get suitable validation methods. d) *Policy makers*: are motivated to promote KS perspectives and educational reforms. e) *Developers*: get new design-space dimensions for engineering.

Future Work (2010-2011). a) Proposing a transdisciplinary syllabus for agent-orientation. b) The same for mathematics and logics. c) Proposing a Master degree in post-industrial engineering. c) The same for doctoral studies.

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